

Flow effect of Kainji Dam on the Distribution of Water Hyacinth in Kolo Creek, Bayelsa State of Nigeria

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Abstract

Water Hyacinth (*Eichhornia crassipes*) is an exotic species whose emergence in the Niger Delta region of Nigeria became noticeable at least within the last two decades. The menace of the water weed in the Niger Delta in recent times has been an issue of Global concern. This must have prompted the appearance in the World Bank (1995) reports on the prioritization of major environmental problems in the Niger Delta, of water hyacinth as invasive exotic species together with *Nypa* palm. The socio-economic and environmental consequences of this invasive weed to the stream users, as well as to the stream ecosystem, leave much to be done. This study focuses on measuring the flow effect of the Kainji dam on the distribution of water hyacinth in the Niger Delta. Run-off data were obtained from secondary sources for Onitsha and Lokoja stations. Differences in annual means for pre-dam and post-dam run-off were statistically significant [$t\text{-stat} = 2.53 > t\text{-stat}_{\text{crit}}(0.05) = 2.228$] for Onitsha and [$t\text{-stat} = 2.96 > t\text{-stat}_{\text{crit}}(0.05) = 2.228$] at Lokoja. The cross-sectional area of the affected stream, velocity and discharge were measured for each segment of Kolo Creek and Esoghoni creek and correlated with area covered by the macrophyte. Our study showed that flow velocity and discharge negatively correlated with the area covered by macrophyte in both wet and dry seasons. The large hydro power electricity dam has apparently affected the flow regime of the downstream sections of the Niger and consequently altered the discharge and the wetted perimeter of the streams in the area creating an enabling environment for the water hyacinth to thrive.

Keywords

Water Hyacinth; Kainji Dam; Hydro Power; Stream; Hydraulic Variables

Introduction

Water hyacinth (*Eichhornia crassipes*) is a floating weed native to the Brazilian Amazon whose invasion in the Niger delta area was first noticed in 1984 (Eborge, 1999). Water hyacinth causes a variety of problems when its mat-like vegetation covers fresh water bodies like streams, rivers and creeks clogging intakes of irrigation and hydropower systems, blocking of canals and river leading to flooding; it serves as micro habitat for a variety of disease vectors. Increased evapotranspiration and destruction of spawning sites for fish have also been reported as one of the effects of water hyacinth invasion. Other socio-economic problems created by this water weed include the obliteration/blockage of transport/access routes and creeks for fishermen and their canoes. In 1995, the World Bank listed water hyacinth alongside *Nypa* palm as invasive exotic species in many tropical, warm and temperate, fresh water habitats worldwide. Water hyacinth has the highest growth rate of any saltwater, freshwater or terrestrial vascular macrophyte and can be labeled as an "ecosystem engineer" or an invasive habitat modifier (ISSG, 2005).

The prevalence of water hyacinth in Kolo creek as well as other fresh water bodies in the Niger Delta region of Nigeria was noted during our field investigation. The weed has not only made some creeks non-accessible, but has altered the physical as well as the bio-chemical processes of the affected ecosystems. This may have interfered with the distribution and abundance of aquatic fauna, most of which are of

nutritional value to man. It is reported that the growth and spread of water hyacinth especially in water with less than 10% salinity is influenced by flow of the water body (Abam, 2001). It is also speculated that since water hyacinth is a fresh water weed with its expansion towards the coast constrained by salinity, this weed finds its way to the Niger Delta as ornamental medicinal herb or from other part of West Africa via the River Niger (Eborge, 1999) which drains a large part of West Africa and discharges its waters, sediments and other loads including exotic species into the Niger Delta drainage system.

Across this River Niger is a large capacity hydropower dam (The Kainji Dam) in Borgu Local Government Area of Niger State, Nigeria. With a reservoir capacity of $15,600 \times 10^6 \text{ m}^3$ and a spill way designed for about $7900 \text{ m}^3/\text{s}$ (Abam, 1999) the Kainji Dam is reported to influence the hydrology of the River Niger (both upstream and downstream) (Iloje, 2005). The international commission on large dams recognized and reported that dams and reservoirs impacts on both the natural as well as the socio-economic environment are "inevitable and undeniable" (ITDG, 2005). The International Rivers Network (Goldsmith and Hildyard, 1984) had also reported that large dams disrupt natural flow, sediment and energy dynamics, resulting in the destruction of the integrity of many ecosystems downstream. In addition to altering the flow regime of rivers, dams also affect the total volume of run-off (Shiklomanov, 1999) and according to Mitchel (1978), as such they allowed the extensive development of the aquatic weeds such as water hyacinth (*Eichhornia crassipes*) and water fern (*Silvinia molesta*) in both Africa and Australia.

Within this context, the research which led to this paper investigated the flow effect of the Kainji Dam on the distribution of water hyacinth along the creeks of Kolo and Esoghoni in Bayelsa State, Niger Delta, Nigeria. Our objectives were first to establish if there is any significant difference between the pre-dam and post-dam construction run-offs at two gauged locations upstream of our study area and secondly to determine if this difference, reflected in the velocity and discharge in the downstream segment of the Niger, has any influence in the distribution of water hyacinth in the Kolo Creek and its tributary – the Esoghoni.

Study Area

The Niger Delta Region generally covers an area of

about 70,000 km^2 and has a somewhat bird feet geometry with an apex located at some 250 km from the Atlantic ocean at Aboh, near Onitsha. The River Niger bifurcates into two main distributory rivers – The Nun and Forcados about 100 km south of the apex, these two rivers further dissect the Delta into several networks of rivers and streams. This is in addition to other rivers and streams that are outside the River Niger system but also flow into the area e.g. Calabar River, Imo River, and River Escravos. The coastline created by this Deltaic network spans over 270 km (ISSG, 2005).

The entire Niger Delta consists of characteristic ecological zones, from the coast to the apex: sandy coastal ridge barriers, brackish saline mangrove, freshwater, permanent and seasonal swamps and lowland forest. The hydrology of the region is particularly sensitive to changes in water quality such as salinity and pollution changes (NEDECO, 1961).

The Niger delta region has a climate characterized by a dry season (November – March) and a wet season (April – October). The annual rainfall varies in the range of 2500 – 3000 mm in the Warri to Port Harcourt axis. Mean temperatures are as high as 32°C with humidity of about 81% between January – March and about 92% in the months of July-August (NDES, 1995).

Kolo creek is a small narrow fresh water, non-tidal stream about 20 m wide and 2 km long from its bifurcation point ($\text{N}004^\circ 58' 56''$ & $\text{E}006^\circ 25' 56''$) at Okarki, Rivers State to Ogbia Local Government area of Bayelsa State (point A on Fig 2 and Yellow arrow on Fig 3). The River runs across fifteen (15) communities. Orashi River, from which Kolo Creek bifurcates from, has its source in a spring from the neighborhood of Orlu (Imo State) and passes Oguta Lake from where it is joined by Rivers Awbana and Njaba and then follows a course as far as Okarki where it is absorbed by the Niger Delta drainage system (Fig 2).

The Orashi River system is independent of River Niger. However, due to the interconnectedness of rivers and streams in the Niger Delta which is low lying (in some places just 3 meters above sea levels), the opening of the dams upstream to discharge floodwaters at the peak of raining season makes the waters of the Niger to overflow into the Orashi and flood all low lying areas interconnecting rivers and streams. The network of rivers in the delta indicates that any increase or decrease in discharge upstream resulting from floods and impoundments of dams significantly affect the

hydrodynamics of the river systems downstream (NEDECO, 1961).



FIGURE 1 MAP OF NIGERIA SHOWING KAINJI LAKE (DAM), LOKOJA THE CONFLUENCE OF RIVERS NIGER AND BENUE, ONITSHA AND THE NIGER DELTA

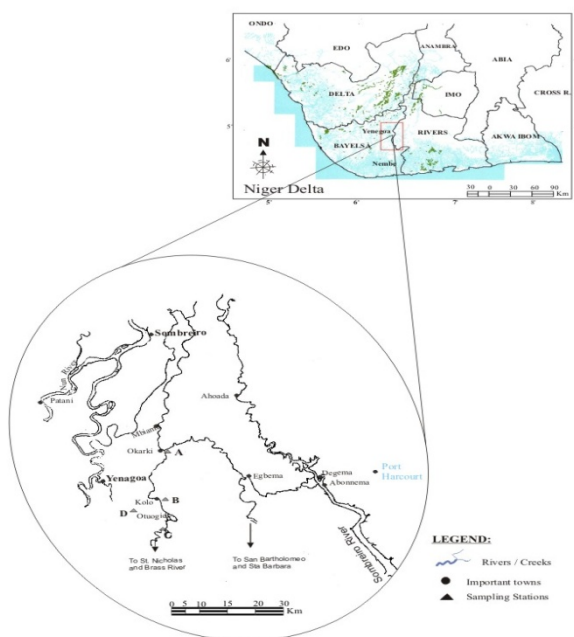


FIGURE 2 MAP OF NIGER DELTA (INSERT KOLO CREEK REGION) SHOWING SAMPLING LOCATIONS (A, B, C, D)



FIGURE 3. BIFURCATION POINT OF ORASHI RIVER AND KOLO CREEK AT OKARKI IN RIVERS STATE. RED ARROW SHOWS ORASHI RIVER AND YELLOW POINTS KOLO CREEK

Methodology

To establish whether there is any significant hydrological differences between pre-dam and post-dam construction phases, we collected and compared stream flow data at two upstream gauged locations of River Niger namely Lokoja (the confluence of River Niger and River Benue) and Onitsha (the apex of the Niger Delta drainage system) for the period 1961 to 1966 (pre-dam construction phase) and 1971 to 1976 (post-dam construction phase).

To determine the velocity and the discharge of Kolo creek, as well as the area covered by the water hyacinth on this river, we divided the 2 km long Kolo Creek and its major tributary (Esoghoni Creek) into four zones, each zone 500 m apart, namely:

- A- Kolo Creek at the bifurcation point at Okarki Rivers State
- B- Kolo Creek at the central or Kolo zone
- C- Kolo Creek at the exit to Otuogidi
- D- Esoghoni creek, tributary of Kolo Creek

In each zone we measured the cross sectional area, velocity and discharge in both the wet and dry seasons. To ascertain the percentage area covered by the macrophyte, we adopted the strip method, i.e. the surface area of each zone is divided into 10 strips according to the Simpson's rule (Straud, 1995); the area of the stream is then divided by the sum of macrophyte covered strips.

Sampling was done at both Dry and Wet Seasons in 2007 and 2008. Parameters measured were then subjected to some test statistics using the SAS Statistical software.

Results and Discussion

Tables 1 and 2 show the annual stream flow statistic of the two upstream of Kolo Creek gauged stations for pre-dam and post-dam construction phases. Figure 4 shows the pre-dam and post-dam mean annual stream flow at Onitsha. The pre-dam stream flow values ranged from 12830-19263 m³/s with a mean of 162965.5 ± 1753.5 cm³/s. Post-dam annual mean ranged from 10386-15862 m³/s with mean values of 14003 ± 1864.8 m³/s.

The differences in the annual means were however statistically significant [t-stat = 2.53 > t-statcrit(0.05) = 2.228] OR [t-stat = 2.53, p < 0.05].

The pre-dam and post-dam annual means did not

follow similar pattern and as such demonstrated a negative correlation $r = -0.5778$.

TABLE 1 PRE-DAM CONSTRUCTION STREAM FLOW DATA

Year	Lokoja Stream flow m ³ /s		Onitsha Stream flow m ³ /s	
	Annual volume	Mean Annual Flow rate	Annual Volume	Mean Annual Flow rate
1961	154,753	12,896	153,959	12,830
1962	218,149	18,179	231,156	19,263
1963	212,100	17,675	223,190	18,516
1964	193,783	16,148	201,807	16,817
1965	186,981	15,581	195,018	16,252
1966	297,161	17,263	212,458	17,705

TABLE 2 POST DAM CONSTRUCTION STREAM FLOW DATA

Year	Lokoja Stream flow m ³ /s		Onitsha Stream flow m ³ /s	
	Annual volume	Mean Annual Flow rate	Annual Volume	Mean Annual Flow rate
1971	169,585	14,132	180,556	15,046
1972	141,145	11,762	155,331	12,944
1973	116,780	9,732	124,631	10,386
1974	166,515	13,876	190,353	15,862
1975	184,553	15,379	184,937	15,411
1976	164,425	13,702	172,423	14,369

Source: Inland Waterways.

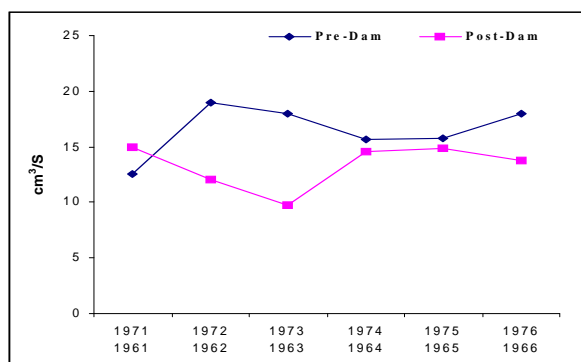


FIGURE 4 PRE-DAM AND POST-DAM MEAN YEARLY RUN-OFF VARIATIONS AT ONITSHA

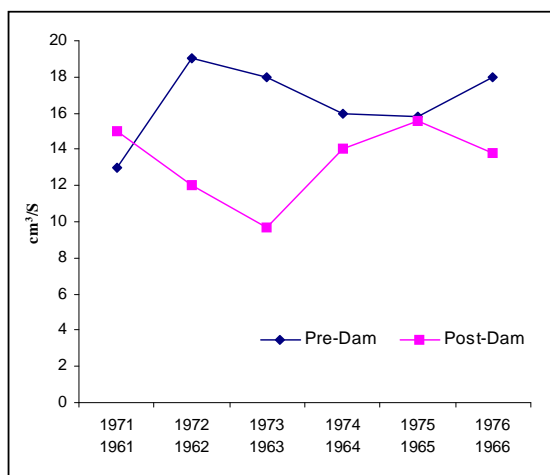


FIGURE 5 PRE-DAM AND POST-DAM MEAN ANNUAL STREAM FLOW VARIATIONS AT LOKOJA

Figure 5 shows the mean annual stream flow data at Lokoja, pre-dam, mean ranged from 9732-15739 m³/s with mean 13097 ± 1839 .

The pre-dam yearly stream flow showed consistently higher values than post-dam means except for 1961 and 1972. The differences in yearly means demonstrated some statistical significance [$t\text{-stat}=2.96 > t = t\text{-stat}_{crit}(0.05) = 2.228$].

TABLE 3 MEAN DEPTH/CROSS SECTIONAL AREA OF SAMPLED LOCATIONS

Sampled Locations	Mean Depth (m)		Cross Sectional Area (wetted perimeter)	
	Dry	Wet	Dry	Wet
A	487	1,016	21.1	102.6
B	462	1,039	21.7	100.1
C	469	992	21.6	102.8
D	281	559	6.7	103.8
Mean			21.5	103.8

The mean depth of the sampled locations varied widely between dry and wet season and between Kolo creek systems (A, B, C) and Esoghoni creek (D). As expected the cross sectional area (wetted perimeter) during flood period i.e. wet season is higher. The seasonal variation in depth profile as well as in cross section demonstrated a marked variation (Table 3). The depth profile of the system varied widely between seasons with a mean of $130 \text{ cm} \pm 34.3 \text{ cm}$ and a wet season mean of $275.2 \text{ cm} \pm 62.9$. The seasonal variations demonstrated a strong positive correlation; $r = 0.813$. The ratio of dry to wet means being 0.45.

TABLE 4.1 VELOCITY MEASUREMENT FOR DRY SEASON 2007

Sampled Locations	February	March	Average Velocity(m ³ /s)
A	1.9	2.1	2.0
B	1.92	2.14	2.03
C	1.85	2.12	2.03
D	1.45	1.53	1.49
Avg. velocity of the four stations			2.02

TABLE 4.2 VELOCITY MEASUREMENT FOR WET SEASON 2007

Sampled Locations	September	October	Average Velocity(cm/s)
A	18.65	19.45	19.05
B	18.88	19.44	19.16
C	18.40	19.56	18.99
D	17.00	18.56	19.78
Avg. velocity of all stations			19.7

The velocity data demonstrated marked variations between seasons. Dry season velocities range 1.45 – 2.21 m³/s with a mean of $2.02 \pm 0.23 \text{ m}^3/\text{s}$; wet season velocities range 17.00 – 19.56 m³/s with mean of $19.067 \pm 0.56 \text{ m}^3/\text{s}$ (Table 4.1 & 4.2). Flow characteristics demonstrated a similar pattern amongst sampling

locations in both dry and wet season with a positive correlation ($r=0.658$). The variation between seasons was statistically significant. ($t\text{-stat} = 14.46 > p = 4.30$ (0.05)).

TABLE 5.1 DISCHARGED FOR DRY SEASON AT SAMPLED LOCATIONS

Station	February	March	Average Velocity(cm/s)
A	40.19	44.41	42.3
B	41.73	46.37	44.05
C	40.03	46.75	43.39
D	9.83	10.23	10.03
Avg. velocity of the four stations			43.25

TABLE 5.2 DISCHARGE FOR WET SEASON AT THE SAMPLED LOCATIONS

Sampled Locations	September	October	Average Velocity(cm/s)
A	1,912.74	1,995.26	1,954
B	2,002.79	2,063.21	2,033
C	1,891.52	2,912.48	1,954
D	665	683.4	674.2
Avg. velocity of all stations			1,979.67

Marked variations were observed between the seasons. Dry season water discharge ranged from 9.83 – 46.75 m³/s with mean of 34.9 ± 14.4 m³/s. while in the wet season, discharged ranged from 665 – 2063 cm³/s with mean velocity value of 1653 ± 566.2 cm³/s. This large difference could be explained by the runoffs from surrounding area (being the peak of raining season) as well as the discharge from the upstream dams).

TABLE 6: PERCENTAGE AREA COVERED BY MACROPHYTE AT BOTH DRY AND WET SEASONS

Stations/Month	A	B	C	D	Mean	Remark
February	60	78.53	58.6	83.32	70.11	
March	66.4	83.47	64.6	89.33	75.95	73%
September	28.1	31.8	26.42	44.53	32.71	
October	27.51	30.15	24.98	27.64	27.57	30.14%

Table 6 shows the macrophyte area cover of the Kolo creek for dry and wet seasons. Mean macrophyte cover during Dry season is 73% while for the Wet season it is 30.14%.

Wet and dry season means had the same distribution pattern demonstrating a perfect positive correlation ($r = 1$) and the ratio of dry to wet means being 2.5.

The differences in the mean macrophyte area covered between wet and dry seasons were statistically significant [$t\text{-stat}=11.856 > p = 1.36$ (0.05)].

Tables 1-5 show that during the Dry season the discharge is low, resulting in shallower wetted perimeter and sluggish flow that encourages the deposition of sediments leading to sand bars and

enabling environment for water weeds to thrive mainly as a result of the reduction of mechanical flushing effect of a good flowing river.

The result did not in any way infer shallower depth to mean shallower coverage in terms of macrophyte cover. It only shows that during the dry season, the water depth is shallower and the width (wetted perimeter) reduced but not in terms of macrophyte cover.

The relationship between the macrophyte area covered and the flow variables, velocity, discharge, cross-sectional area and depth explains the influence of discharge on all other variables and how this in turn affects the growth of the macrophyte

Conclusion and Recommendations

This study shows that the construction of the Kainji dam has obviously altered the flow regime of the downstream sections of the River Niger. The significant difference between pre-dam and post-dam mean annual run-off values can attest to that fact (Fig.2 and 3).

It can also be deduced from this study that the percentage of macrophyte area covered is inversely proportional to the flow variables, velocity, cross-sectional area, discharge as well as water depth. Thus the high prevalence level of water hyacinth is a factor of flow reduction which is consequent upon the Kainji dam.

The annual floods of the Niger usually flush out all weeds to the high seas where salinity affects the growth and expansion of the weeds (World Bank, 1995), however with the alteration of the flow regime, the natural flushing mechanism of Kolo Creek have adversely be hampered resulting in the prevalence of the water weeds as a result of increased deposition of sediments. The conclusion is that reduction in flow velocity might have resulted in the widespread occurrence of the water hyacinth, Our conclusion is anchored on the fact that prior studies (Eborge, 1999)) on the causal factors of the prevalence of water hyacinth highlighting eutrophication resulting from river pollution, and other causes negatively correlated. The findings in this study agree with the submission of Haslam (1978).

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